



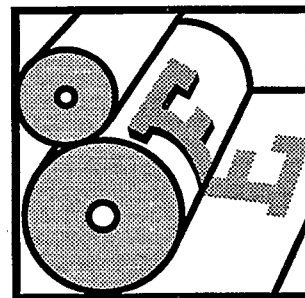
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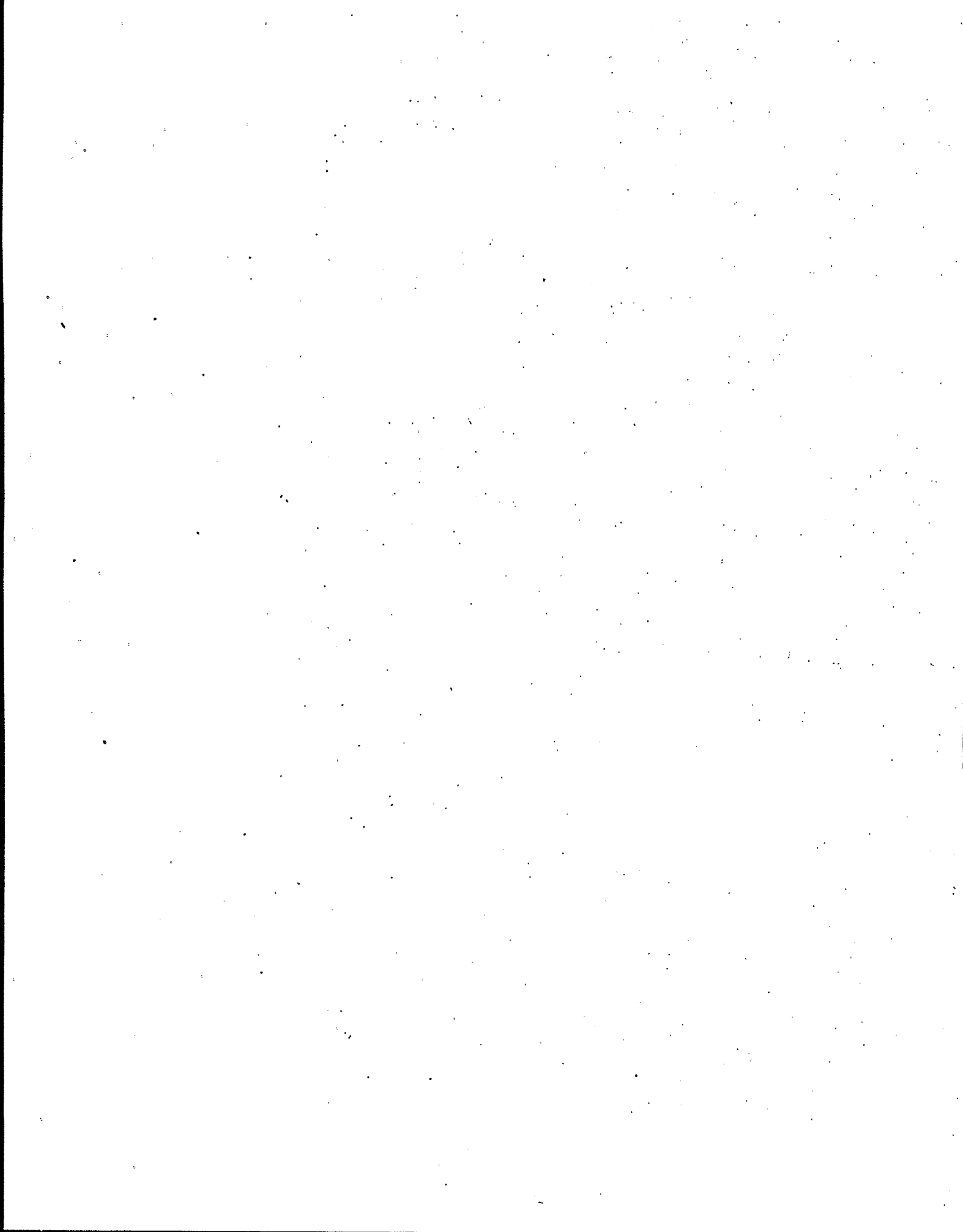
EPA 744-R-96-001
September 1996

Pollution Prevention Experiences in Three Flexographic Printing Facilities

Design for the Environment
Printing Project



Recycled/Recyclable
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contains at least 50% post-consumer recycled fiber



**POLLUTION PREVENTION EXPERIENCES IN THREE
FLEXOGRAPHIC PRINTING FACILITIES**

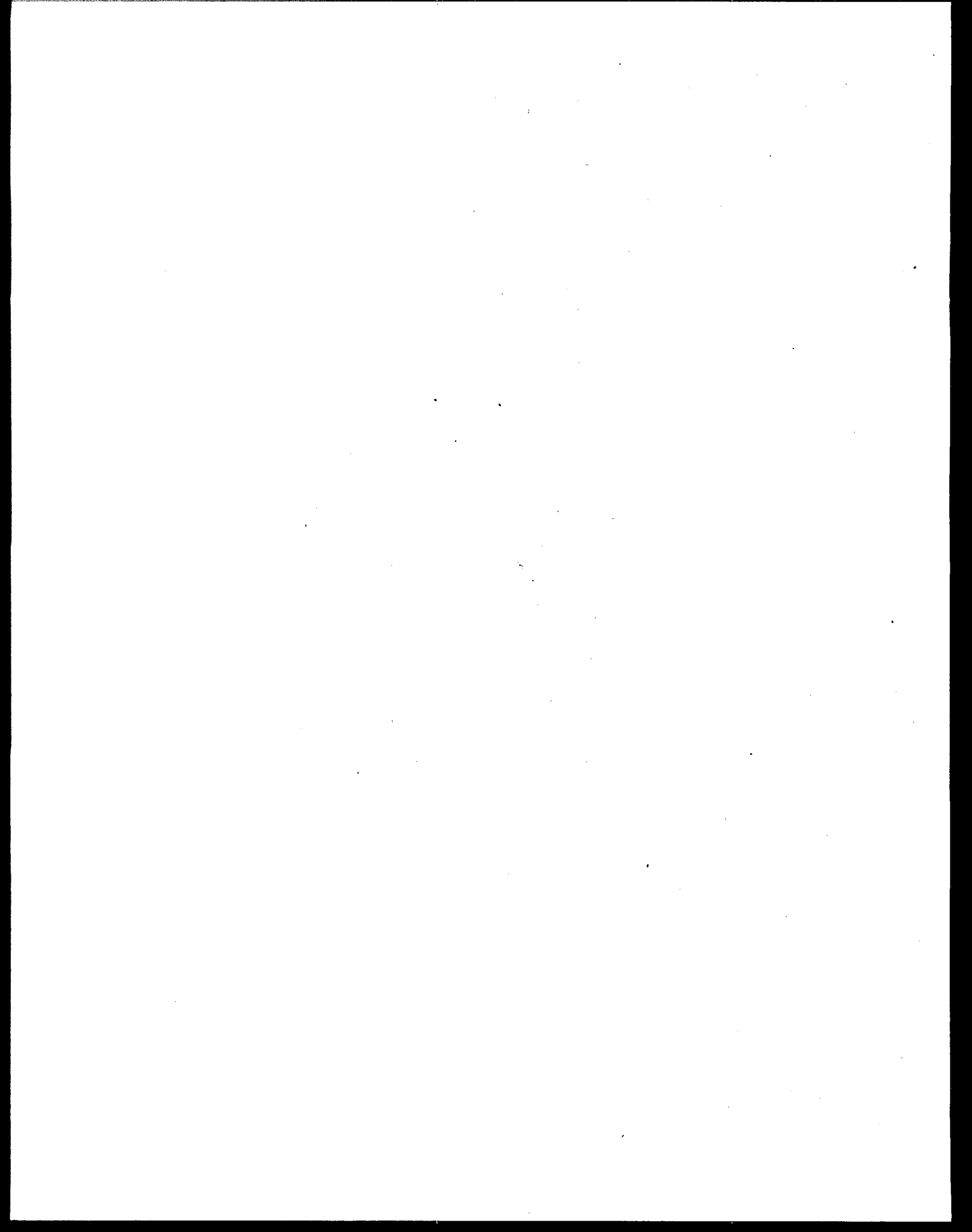
Prepared for:

**The Design for the Environment (DfE) Program
United States Environmental Protection Agency
Office of Pollution Prevention and Toxics**

July 1996

By

**The Center for Business and Environmental Studies
California State University, Hayward
Under Grant # X-820802**



For More Information

To learn more about the Flexography Project of EPA's Design for the Environment Program or to obtain this document or additional information on other related materials, please contact:

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A special thank you is owed to Fred Shapiro, Environment and Safety Consultant to the Flexographic Technical Association (FTA), and president of P.F. Technical Services, Inc. Fred was instrumental in providing us the background and technical expertise related to flexography, as well as spending much time and patience addressing the issues involved in this study.

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The report is an amendment to the scope of work for Grant # X-820802, which was a focus group study of Lithographers and Screen Printers on the "Investigation of Methods of Informing & Motivating Change in a Portion of the Printing Industry," completed March 1996. These studies were commissioned by the United States Environmental Protection Agency (EPA), Office of Pollution Prevention and Toxics (OPPT), and conducted by the Center for Business and Environmental Studies (CBES), at California State University, Hayward, from October, 1993 through June, 1996.

PURPOSE OF THE REPORT

This report highlights the experiences with water-base ink versus solvent-base ink of three flexographic printing facilities. The primary purpose of this study was to analyze the motivations of the facilities in selecting their specific pollution prevention methods.

INTRODUCTION

EPA initiated the Design for the Environment (DfE) Program to promote the use of environmentally sound technologies and products in manufacturing. Through the Program, EPA formed the Design for the Environment Printing Project in partnership with printing industry trade associations, such as the Flexographic Technical Association (FTA), Screen Printers Association International (SPAI), and the Printing Industries of America (PIA), as well as individual printers and suppliers. An important first step in developing an overall strategy for pollution prevention, these partnerships are intended to determine the most effective ways to reach the printing industry audience with messages regarding the "how to" of pollution prevention.

The format of this report provides background on the flexographic industry, including the printing processes, pollution concerns, and regulatory requirements. Three case studies are then presented, one of which is anonymous. Finally, the overall findings of the report are discussed.

The case studies follow a typical case study methodology, reporting on the following information:

1. **Facility profile**, providing a brief description of each flexographic printing facility.
2. **Issues involved in deciding to use water-base ink versus add-on controls**, examining the motivations of each flexographic facility in arriving at its particular pollution prevention strategy.
3. **Issues and/or problems during implementation of the new system**, describing the experiences of each flexographic facility during the conversion process.

4. **Results of the change to the new process**, assessing the outcome of the pollution prevention method chosen.
5. **Impact of external factors**, describing the roles of trade associations, ink suppliers, and consultants during the various stages of conversion.
6. **Future developments**, describing ways that each facility expects to further improve efficiency and/or reduce pollution.

BACKGROUND OF FLEXOGRAPHY

The printing industry is comprised of several types of printing employing one or more processes, such as lithography, letterpress, flexography, gravure, screen printing, and various plateless technologies. Flexographic printing employs plates with raised images, and only the raised images come in contact with the substrate (the film) during printing. Typically, the plates are made of plastic, rubber or some other flexible material, which is attached to a roller or cylinder for ink application. Ink is applied from an engraved metering roller to the raised image on the plate, which transfers the image to the substrate.¹

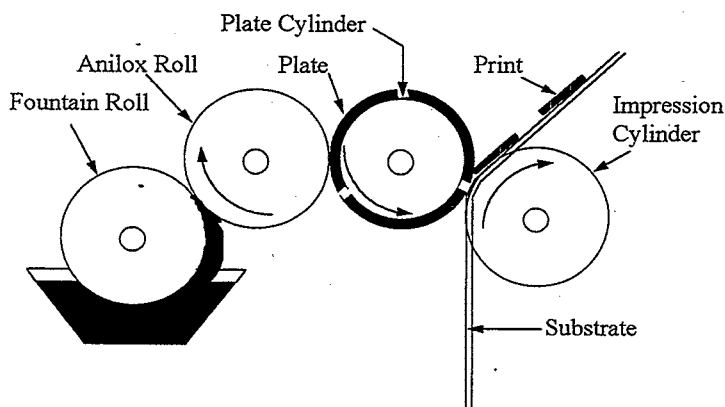


Figure 1: Typical print station. A. Ink fountain with fluid ink. B. Rubber ink-fountain roll. C. Reverse angle doctor blade (if used in the system). D. Ink-metering (anilox) roll. E. Printing plate cylinder. F. Substrate traveling through press. G. Impression cylinder.

Source: Introduction to Flexography

In the typical flexographic printing sequence, the substrate is fed into the press from a roll. The image is printed as the substrate travels through a series of stations, with each station printing a single color. Each station is made up of four rollers. The first roller (also known as a fountain roll) transfers the ink from an ink fountain (tray) to the second roller, the meter roller. The

meter roller (also known as an anilox roll) meters the ink to a uniform

thickness onto the third roller, the plate cylinder. The substrate moves between the plate cylinder and the fourth or impression roller, which supports the substrate.²

The printed web (substrate) proceeds through color printing stations and between color drying chambers to dry the ink before the next station. Upon completion of the printing and drying of the last color in an overhead drying tunnel, the finished product is rewound onto a second roll, hence

the term “roll-to-roll.” Many operations can be performed in-line after the substrate has been printed and dried, while still unwound. Some types of flexo presses are equipped with a sheeter that delivers sheets instead of rolls, or places them in line with bag and box making equipment to deliver finished products.

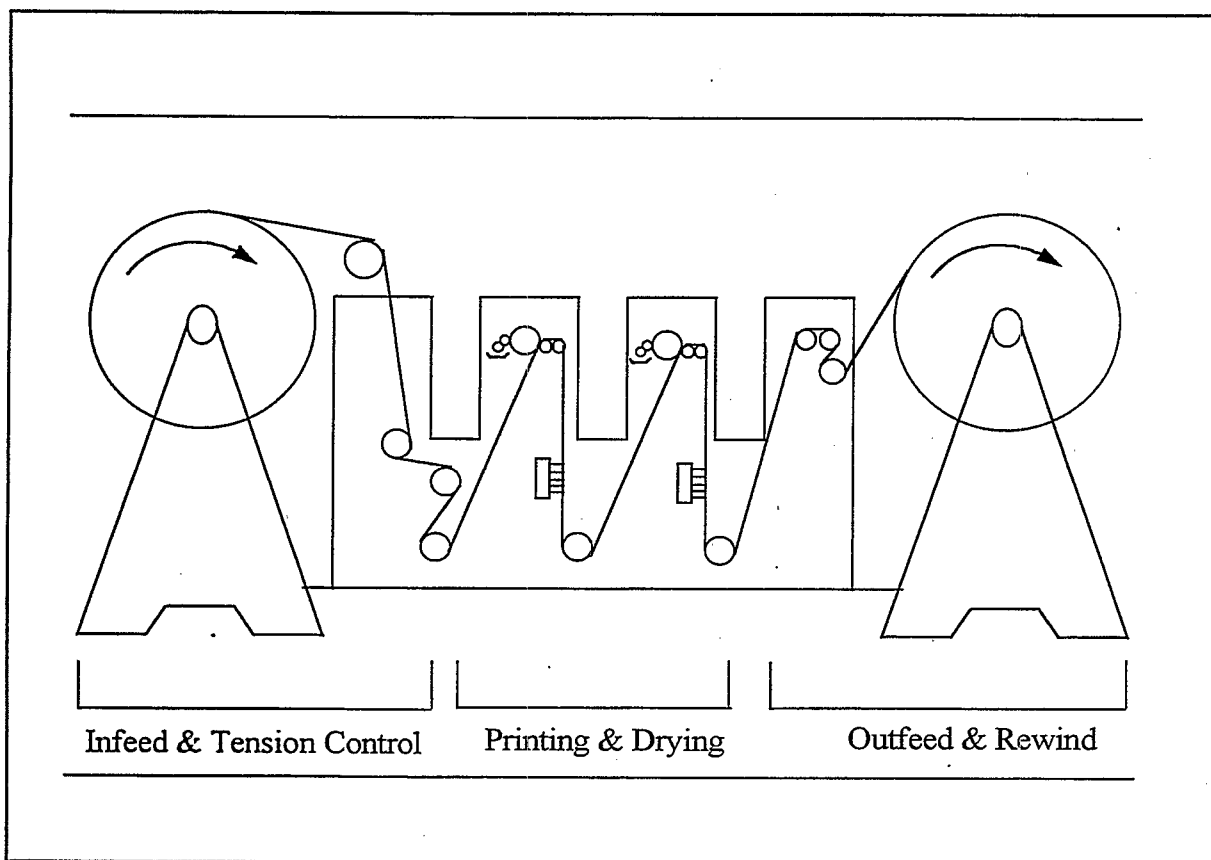


Exhibit 1: Webfed Rotary Flexographic Press

Source: EPA 1994

The system can also run with a doctor blade, which improves ink distribution by wiping excessive ink off the anilox roller. Modern presses are now equipped with enclosed doctor blade systems

which eliminate the fountain roller and ink fountain, thereby reducing evaporation loss.³ Using ultra-violet (UV) inks eliminates the volatile solvent in the ink, while water-base ink produces relatively low emissions of Volatile Organic Compounds (VOCs) as compared to solvent-base ink.

The width of flexography presses ranges from 4.5 inches up to 115 inches. The ink tray (fountain) used on larger (wide-web) presses is very long, allowing for significant evaporation of ink if an enclosed doctor blade box is not used. Flexographic printers use a wide variety of substrates, ranging from paper to exotic plastic films. Printers have more success with water-base inks on papers and other absorbent substrates. Wide web printers encounter physical problems when printing on films due to the surface tension differences between the materials and the inks. Narrow web printers use a more limited range of materials and work with narrow width and smaller circumference rollers, making it more cost effective to use both water-base and UV curable inks.

The inks used in flexography are fast-drying and of low-viscosity. These inks lie on the surface of non-absorbent substrates and solidify when solvents are removed, making flexography ideal for printing on impervious materials such as polyethylene, cellophane and other plastics and metallized surfaces. Also, the soft plates, which are relief plates of varying durometers (rubber hardness), allow quality printing on compressible surfaces such as cardboard packaging.⁴

With low cost plates and a relatively simple press, flexography is one of the least expensive and fastest growing printing processes. According to the Flexographic Technical Association, flexography accounts for 85 percent of printed packaging, such as plastic wrappers, corrugated boxes, milk cartons, labels, and foil and paper bags.⁵ In 1991, flexographic printing accounted for 17 percent of the total value of US printing industry output (excluding instant and in-plant printing), which was estimated at \$161 billion.⁶ Between 1991 and 2025, however, flexography's share of the printing market is expected to increase to 21 percent or more. In addition, the total printing industry's dollar volume is expected to grow by 3.8 to 5.3 percent during that same time

period. Growth areas for flexography are expected to be pre-printed labels for corrugated boxes, pressure sensitive labels, newspaper inserts, comic books, directories, and catalogs.⁷

Of a total of 59,636 plants in the United States with printing presses, only 1,587, or 2.7 percent, have flexographic presses. Flexographic printers, however, tend to be larger than printers using other processes. Almost 55 percent of plants with flexographic presses have 20 or more employees, compared to less than 16 percent for the printing industry as a whole.⁸

Flexographic printing operations use materials that adversely affect air, water, and land. Certain chemicals involved in printing, such as solvents, volatilize, which contributes to air emissions from the printing facility and to smog formation. Chemicals may be discharged to drains and effect freshwater or marine ecosystems. Solid wastes, such as film and paper waste, contribute to existing local and regional disposal problems.

The major concern regarding the flexographic industry is the release of oxidants into the atmosphere. These oxidants result from chemical reactions by organic compounds and other non-methane VOCs. The flexographic industry releases approximately 99 percent of its pollution to the air, and it is these emissions that the study will focus on.⁹

REGULATIONS GOVERNING THE FLEXOGRAPHIC INDUSTRY

The Clean Air Act of 1970 set up the first national system to regulate and enforce air pollution standards. The Act has been amended several times and now provides a comprehensive program, administered primarily by the states, to reduce hazardous emissions. It is designed to "protect and enhance the nation's air resources so as to promote the public health and welfare and the productive capacity of the population."¹⁰

In particular, regulatory agencies work to reduce oxidants in the atmosphere, as set forth in State Implementation Plans (SIPs). The oxidant plan portions of SIPs must reflect the application of reasonably available control technology (RACT) to pollution sources in non-attainment areas. Non-attainment areas do not comply with local air quality standards and usually experience greater scrutiny. RACTs aim for the lowest possible emission level that any source can reasonably attain. This level is derived from EPA studies published in control techniques guidelines (CTG), a technical document providing plant owners, state regulatory agencies and the EPA guidelines for defining RACTs. The CTG document for flexography (Volume VIII, Graphic Arts-Rotogravure and Flexography) specifies low-solvent inks to reduce VOC emissions. For processes and applications that can use these complying inks, emissions can be reduced to acceptable levels without further technology. Using these inks is not feasible for some applications. In these cases, the CTG document states that incineration or solvent recovery are the most reasonably available control technology.¹¹

The oxidants released during printing result from chemical reactions by organic compounds and other non-methane VOCs. Some 40% of these compounds come from cars and other vehicles. The second largest source, about 27%, is from operations that use solvents, and the EPA identifies the flexographic printing industry as part of this group.¹² These solvents are organic compounds in liquid form, and are found in purchased ink and in solvents added to reduce inks

while printing to maintain the appropriate level of viscosity. The vapors released into the air during the drying process interact with sunlight to form ozone (a bluish gaseous reactive form of oxygen): one of the EPA's main concerns, because of its effects on human health.¹³

The Occupational Safety and Health Administration (OSHA), which is charged with protecting health and safety in the workplace also oversees the flexographic industry. OSHA is concerned with overexposure of employees to solvents used in printing which can have harmful health effects. Threshold limit values for each solvent are listed in OSHA's "Table Z" in the Hazard Communication Standard of November 25, 1983.¹⁴ As flexographic companies comply with the CTG document, they also reduce employee exposure to the solvents.

This study attempts to document the actual experiences of three flexographic printers who have made the choice between the use of low-solvent inks and incineration as a means of complying with both pollution prevention and employee safety regulations.

METHODS OF VOC COMPLIANCE IN THE FLEXOGRAPHIC INDUSTRY

The two methods of compliance in reducing volatile organic compounds emissions for flexographic printers, set forth in the CTG document, are the following:¹⁵

Method 1: Use of Low-Solvent Inks:

- Water-base inks, which contain no more than 25% by volume of organic solvent in the volatile portion.
- Compliant high-solid inks, which contain 60% overall solids by volume, make drying difficult because of the relatively high latent heat of water. Also, these inks do not apply successfully to substrates that are commonly used in flexography. In addition, they are not currently available. Our focus is therefore on water-base ink, which has been successfully used for some flexographic applications.

Method 2: Add-On Controls:

- Solvent recovery removes organic solvents in vapor form from the air, turns them back into a liquid and recycles them into the existing ink supply. After this process, the airstream should contain minimal amounts of VOCs and be well within allowable limits. The most common solvent recovery technique is carbon absorption. This process uses activated charcoal or carbon to separate solvents from an airstream. When the vapor-laden air from the dryers passes through a bed of this carbon, the carbon simply catches and retains the solvents. When the solvent can be separated readily from the water and reused as a raw material, then cost savings make the use of solvent recovery systems a good choice. Unfortunately, most solvents used in flexographic printing are blends of alcohols and acetates, many of which are water soluble, rendering carbon absorption technically unusable for flexo printers.

- Incineration, or destroying solvents by oxidation, is a process that uses heat and oxygen to convert organic solvents to carbon dioxide and water vapor. The equation is:

VOC + oxygen + heat = carbon dioxide + water.

Two incineration techniques are appropriate for compliance:

1. Thermal incineration, where VOCs are exposed to 1,400°F to 1,500°F with a dwell time of 0.3 second to 1.0 second. This is the time interval during which elements must remain in contact or in a static position.¹⁶
2. Catalytic incineration, in which a catalyst is used to start a chemical reaction that can proceed under different conditions and at a lower temperature than otherwise possible. The catalyst induces oxidation at 500°F to 700°F and requires a dwell time of about 0.7 second.

To compare the difference in capital outlay between the incineration system and water-base ink method, several attachments are included in Appendix A. (These charts were provided by Fred Shapiro of P.F. Technical Services, Inc., and were prepared for a client to illustrate the variable capital expenditures required to convert his three presses to water-base ink compared to converting to an incineration system).

In addition to using low-solvent inks or add-on controls, there are a number of other pollution prevention opportunities for flexographic printers to reduce VOC emissions during the printing process on a smaller scale. These opportunities include:¹⁷

- Improving housekeeping and operating practices, such as covering reservoirs and containers, scheduling jobs according to increasing darkness of ink color, and using wipes until fully saturated. These procedures can minimize solvent losses from inks and cleaning solutions.
- Reducing ink vaporization by using diaphragm pumps which do not heat ink as much as mechanical vane pumps.
- Recycling waste solvents on-site or off-site. Segregating of solvents may allow a second use (e.g., for equipment cleaning or ink thinning).

- Recycling of certain waste inks where possible.
- Recycling of product rejects where possible.
- Using alternative ink and cleaning products with reduced VOC emissions. Lowering the VOC emissions from printing and press clean-up may be accomplished using water-base or UV curable inks (rather than solvent-base inks) where possible and using safer (less toxic) solvents, and low-VOC or VOC-free cleaning solutions.
- Installing automatic ink levelers to keep ink conditions optimal.
- Using automatic cleaning equipment, which can often be retrofitted to existing presses and operations. Typically, lower volumes of cleaning formulations are applied with such cleaning equipment. Air contact and thus volatility are then reduced.
- Minimizing finished product rejects by automating monitoring technologies which detect tears in web and press performance.

The final steps in making a printed product may involve folding, trimming, binding, laminating and embossing. Typical waste streams include: scrap substrate from trimming, rejects from finishing operations, and VOCs released from adhesives. Pollution prevention opportunities at this stage of the process include:¹⁸

- Collecting and reclaiming recyclable materials.
- Replacing VOC-base adhesives with water-soluble adhesives (binding adhesives that are not water-soluble may interfere with later recycling), hot-melt adhesives, or mechanical methods in laminating and converting operations.

CASE STUDIES

This section presents the findings of on-site visits by the study team at three flexographic printing facilities: Emerald Packaging, Packaging Specialties, and Firm X. These facilities were selected, in consultation with flexographic industry associations, by the DfE Flexography project of the EPA. The three companies voluntarily agreed to participate in the study. The site visits took place during March and April of 1996.

The on-site visits were to enable the research team to document the actual experience of those involved in the decision making and implementation process of the selected pollution prevention method. All participants were cooperative and sources of valuable information, however, there were two areas of information that each of these companies declined to reveal publicly:

- financial information, such as cost/benefit analysis data related to the conversion; and
- composition of the ink, as these companies had spent much energy and capital in creating just the right ink for the substrates being used by them, and were unwilling to pass this information on to competitors.

The focus of this study is on the experiences of the three flexographic printing facilities as they implemented either low-solvent ink or add-on controls. Each of the three facilities had its own motivation to select the pollution prevention method currently in place, as described in the following case studies. The facilities being studied do not deal with pre-press operations, such as image making and plate making, therefore the pollution prevention focus of this study is on press and post-press operations.

EMERALD PACKAGING

Emerald Packaging, located in Union City, California, decided in the late 1980's to transfer from solvent-base ink to water-base ink. The company received strong support from Zeneca Specialty Inks, Emerald's main ink supplier, who first introduced the company to water-base ink, and worked closely with Emerald to improve the ink's quality and reliability. Although the decision was mostly compliance driven, management believed that there would be an eventual cost benefit to the water-base ink. Management used a gradual process of converting to water-base ink, in part due to the trial and error nature and initial poor results of these inks. In 1988, 3200 pounds of water-base ink were used by Emerald Packaging, and by 1991 this had increased to 100,000 pounds. For the last five years this facility has used entirely water-base ink for its operations. Although others in the industry had perceived a decline in the quality of their products as a result of converting to water-base ink, during and after the time of implementation at Emerald Packaging, it did not experience a single return of any of its finished products.

1. *Facility Profile*

Number Of Employees:	97 (includes 9 in front office)
Annual Sales:	\$10 to 20 million (1995)
Sales Area:	Western United States (broker network)
Main Product:	Produce packaging manufacturing (85% of sales)
Plant Size:	46,000 square feet
Office Size:	5,000 square feet
Other Features:	2-3 week turnaround of orders; average of 10-20 days backlog of client orders
Operating Schedule:	3 shifts/7 days a week
Printing Presses:	4 flexographic presses with enclosed doctor blade boxes, 2 six rollers and 2 four rollers
Primary Ink:	Water-base
Primary Substrate:	Polyethylene
Plate Making:	Out-sourced
VOC Emissions Permit:	Maximum of 31.5 tons/yr.
Current Emissions:	14-15 tons/yr.
Ink Cost:	4-5% of total sales
Ink Waste:	Thirty-six 55 gallon drums/yr.
Ink Waste Cost:	\$7,920/yr. (\$220/55 gallon drum)

2. *Issues Involved In Deciding To Use Water-Base Ink Vs. Add-On Controls*

Compliance drove Emerald Packaging management to migrate to water-base ink. However, the decision was made well before experiencing any external regulatory pressure. The process began in 1988, and the transfer to sole use of water-base ink on all presses was completed by 1992. Management used a pro-active approach in addressing pollution prevention, as it believed that eventually regulatory agencies such as the Bay Area Quality Management District would force them to implement pollution prevention measures.

Emerald Packaging reviewed two alternatives in preventing pollution: water-base inks versus an incinerator. Cost estimates for an incinerator were given in 1989 by two major manufacturers, Reeco and JWP:

	JWP	Reeco
Equipment	\$1,508,000	\$1,920,000
Soft Costs @ 12%	181,000	230,000
Sales Tax @ 8.25%	<u>139,000</u>	<u>177,000</u>
Total	\$1,828,000	\$2,327,000
Amortized (10% interest) (formula was not available)	\$ 290,000/yr.	\$ 369,000/yr.
Fuel (Natural gas)	\$ 359,000/yr. (\$55.83/hr)	\$ 213,000/yr. (\$33.00/hr)
Electricity (\$31.03/hr)	\$ 199,000/yr.	\$ 199,000/yr.
Maintenance (\$15.00/hr)	<u>\$ 90,000/yr.</u>	<u>\$ 90,000/yr.</u>
Total Annual Cost	\$ 938,000	\$ 871,000

The following is an estimated cost outlay of the necessary investments to water-base ink provided by the production manager at Emerald Packaging:

	Per item:	Total for a 4-roller press	Total for a 6-roller press
Corona treater:	\$ 30,000	\$ 30,000	\$ 30,000
Anilox roller:	\$ 5,000	\$ 20,000	\$ 30,000
Drying equipment:	\$ 3,000	\$ 12,000	\$ 18,000
Enclosed doctor blades:	\$ 10,000	\$ 40,000	\$ 60,000
Miscellaneous:	\$ 4,000	<u>\$ 16,000</u>	<u>\$ 24,000</u>
Total investment per press:		\$118,000	\$162,000

The total investment for Emerald Packaging to convert to water-base ink was about \$400,000, which was based on two 4-roller presses and one 6-roller press.

Although some of the costs of converting to water-base ink (such as operating costs) were not fully disclosed, management believed that water-base inks had several advantages over an incinerator:

- Due to expected market growth, Emerald would need to move its operations in the next few years, and with it the incinerator, at an additional expense.
- Reverting to water-base ink was the environmentally right thing to do, as it reduced or eliminated VOCs, the solvent odor in the plant, and the energy costs of an incinerator.
- The investment of converting to a water-base ink system appears to be considerably less

than the investment of acquiring an incinerator (see above).

- Should the trial and error stage of implementing water-base ink be unsuccessful, Emerald still had the choice of reverting to an incinerator, while still being in compliance during the implementation period.
- If successful, being one of the first flexo printers in its market to convert to water-base ink could give Emerald Packaging a competitive edge.

3. *Issues And/Or Problems During Implementation Of The New System*

One of the first issues was the poor results in quality and reliability of the water-base ink. Because the ink would not dry and because of problems with the ink density and poor pigment, the ink bled and/or applied poorly to the substrate. By experimenting with free samples of water-base inks from Zeneca, Emerald's main ink supplier, technicians were able to give continuous feedback to Zeneca and eventually help create a satisfactory water-base ink for their substrates. First, a thicker layer of ink was tried, which improved the color and transfer of the ink onto the substrate; however, it still took too long to dry. Ultimately, a combination of factors made water-base ink application successful:

- The substrate (polyethylene) was treated to a higher dyne level on the printing side to increase the surface tension, improving the transfer, adhesion, and drying time of the ink.
- Enclosed doctor blades were attached to the anilox rollers which greatly improved the distribution of the ink onto the roller and eliminated evaporation, thereby increasing the consistency of the ink lay down.
- The drying process was improved by increasing the airflow, rather than using heat.
- The ink supplier created a lower viscosity, higher solids ink which dried more easily, and

at the same time improved the density to maintain color.

- During the transition, Emerald used a white solvent-base ink as the ground layer for water-base ink in order to enhance the gloss.
- Press operators were supportive in implementing this new technology and provided feedback on the outcome of numerous trials, which aided the improvement of the water-base ink for Emerald's operations.
- Running the presses non-stop reduced start-up and shut-down costs, which prevented additional problems with the ink quality.

Initially, Emerald Packaging used water-base ink on just one of its four flexographic printing presses, in order to minimize any loss of productivity.

4. *Results Of The Change To The New Process*

Although it took Emerald (and Zeneca) several years to perfect the water-base ink needed, as well as improve the printing surface of the substrate, there remain many advantages and only a few disadvantages compared to solvent-base ink.

The disadvantages are:

- Higher price (20%) for water-base ink (no dollar amounts were provided).
- Slower runs (10-15%) with water-base ink versus solvent-base ink (actual numbers were not provided).
- Decrease in gloss of water-base ink.
- Higher labor costs for better trained personnel to handle water-base ink (no dollar

amounts were provided).

- Major investment needed in new equipment to operate water-base ink, i.e.: enclosed doctor blade boxes, corona discharge treaters, drying system, etc.

The advantages are:

- Water-base ink has much better mileage (20-30% more) than solvent-base. Mileage is the usage factor of an ink, and refers to the amount of ink used to cover a certain area of printed surface (actual numbers were not provided).
- Cost of water-base ink per impression is actually less than solvent-base ink (no dollar amounts were provided).
- Recovered water-base ink is recycled without filtering.
- Color quality is more consistent with water-base ink.
- Slower runs (with water-base ink) cause lower VOC emissions (actual numbers were not provided).
- Emerald's annual VOC emissions is between 14 to 15 tons using water-base ink, while it has a permit that allows annual VOC emissions of up to 31.5 tons. While using solvent-base ink and only two presses, Emerald emitted well over 50 tons of VOC annually.
- Safer environment for employees.
- Rubber plates are less hazardous to clean (solvent-less).
- Less waste ink as the ink is easier to recycle.
- Avoidance of major investment for an incinerator plus high operating costs.
- Peace of mind in compliance situation.

5. *Impact Of External Factors*

While the decision was mainly instigated by management to pursue a pro-active pollution prevention program, Emerald's ink supplier, Zeneca, played a pivotal role in creating the right ink and in working closely with those involved at the plant. Management also made use of its trade association, the California Film and Extruders Conversion Association (CFECA), to obtain information and feedback from other members, which assisted in Emerald Packaging's decision making and implementation process.

6. *Future Developments*

Management at Emerald Packaging hopes to eventually use photopolymer plates in the production process. Photopolymers are light-sensitive materials, which, when used in flexographic printing plates, are similar to rubber in that they are flexible, resilient and have the printing image in relief. These plates are easier to clean, reducing the amount of solvent necessary in the cleaning process. Moreover, photopolymer plates provide a better defined ink image, which should reduce both initial ink consumption and the quantity of defective final product.

A recent trend that seems likely to continue is an increase in local companies leaving the Bay Area, in search of less strict environmental regulations and a more stable work force elsewhere. Management is concerned that this is leading to an unfair competitive situation.

PACKAGING SPECIALTIES

Packaging Specialties, located in Fayetteville, Arkansas, was forced into compliance in 1989 by the Arkansas Department of Pollution Control and Ecology, which issued it two Consent Administrative Orders (CAO) in 1990 and 1991, resulting in fines totaling \$64,500.

The General Manager of Packaging Specialties initially decided to convert all flexographic printing presses from using solvent-base ink to using water-base ink at that time, in order to comply with VOC emission regulations. This decision was made primarily for three reasons:

1. It was possible to reduce VOC emissions immediately using water-base ink, whereas installing an incinerator required a major capital investment and resultant delays.
2. Water-base ink was believed to be more environmentally friendly than the incineration method, in light of the increased energy consumption required to operate it.
3. Converting to water-base ink was to be a permanent solution, while an incinerator was considered a short-term, quick-fix solution, and eventually would need to be replaced as the company kept growing.

Packaging Specialties uses three different substrates: polyethylene, poly vinyl chloride (PVC) and Cryovac. Because each requires different printing techniques, composition of the ink is a complex issue. PVC allows for stretching after printing, while Cryovac allows for shrinkage after printing, and both require high-performance inks. Management had experimented with water-base ink during the late 1980's and felt confident that conversion to water-base ink would be successful.

During a 14 month period in 1991 and 1992, only water-base ink was used on all presses. Due to poor print quality, regulatory pressure to comply with VOC emissions, and increased returns from clients, including its largest customer who threatened to take its business elsewhere if quality didn't improve, management felt compelled to install an incinerator system and revert to using solvent-base ink. As print quality has become more important, and an incinerator with ventilation system is in place, management considers it extremely unlikely that the facility will return to solely water-base ink in the short-term, unless regulatory agencies strongly curtail the VOC emission permit allowance. However in the long-term, management expects to implement water-base and/or UV-base inks to remain in compliance. Now that Packaging Specialties has invested in an incinerator system, it has little economic motivation to change soon. This case study will describe the implementation of the incinerator with ventilation system and its results and future expectations.

1. Facility Profile

Number Of Employees:	85 (including 20 in front office)
Annual Sales:	\$15 to 20 million (1995)
Sales Area:	South Central US. and West Coast (sales force)
Main Product:	Poultry packaging manufacturing (70% of sales)
Plant Size:	50,000 square feet
Other Features:	2-3 week turnaround of orders; average of 4-5 days backlog of client orders
Operating Schedule:	3 shifts/5 days a week
Printing Presses:	9 flexographic presses, 3 with doctor blades, all presses with 5 to 8 rollers
Primary Ink:	Solvent-base
Primary Substrate:	PVC, polyethylene, and Cryovac
Plate Making:	Out-sourced
VOC Emissions Permit:	Maximum of 93.3 tons/yr.
Current Emissions:	35-40 tons/yr.
Ink Cost:	6% of total sales (includes in-house ink technician)
Ink Waste:	Sixty 55 gallon drums/yr.
Ink Waste Cost:	\$4,500/yr. (\$75/55 gallon drum)

2. Issues Involved In Deciding To Use Water-Base Ink Vs. Add-On Controls

Packaging Specialties experienced two periods of decision making. The first occurred in 1991, when, forced to comply with environmental regulations, the General Manager decided to transfer to using water-base ink. The second occurred 14 months later, when management reverted to solvent-base ink and installed an incinerator and ventilation system.

In 1991, Packaging Specialties was instructed by the local regulatory agencies to comply with environmental regulations by installing an incinerator. The company's General Manager, however, was convinced at the time that transferring to water-base ink would bring the facility into compliance in the shortest possible time and at the lowest capital investment (figures were not available for the study). Since the local regulatory agencies were not familiar with the time frame necessary for implementation to water-base ink in 1990, management spent considerable time and effort justifying its approach to the local regulatory agencies.

Eventually, all presses were operated using water-base ink. This meant that the composition of the ink had to be changed, the substrates treated, the plant employees trained, and a slight decline in product quality was to be expected. The actual cost of this conversion was estimated at \$915,696, considerably higher than anticipated.

Although great effort was undertaken to perfect all aspects of the water-base ink conversion, several factors worked against it:

- The ink supplier, GPI, was not able to provide a consistently successful water-base ink, in particular for the PVC and Cryovac substrates, and management could not find any other

ink manufacturers with success in this regard. There is very little use of PVC and Cryovac in the flexographic industry, creating little incentive for ink suppliers to develop a water-base ink specifically for these substrates.

- Due to compliance pressure, Packaging Specialties was not able to undergo a trial and error phase, like others in the industry.
- Customer complaints and an increase in product returns (up to 5% of all finished products) forced Packaging Specialties to print using solvent-base ink to appease certain clients, and eventually led to more production based on solvent-base ink, increasing the need for an incinerator.
- The up-front cost of water-base ink was about 50% more than solvent-base ink for Packaging Specialties, while there were no perceived savings in using less water-base ink.
- Whereas enclosed doctor blade boxes are highly recommended on all rollers when using water-base ink, none of the nine flexographic presses at that time had either reversed angle doctor blades or enclosed doctor blade boxes on its rollers. Doctor blades greatly reduce the amount of ink applied, which partly explains the lack of perceived savings on the mileage of water-base ink. It should be noted that this aspect was not emphasized by GPI or other industry sources during the conversion to water-base ink in 1991.

3. Issues And/Or Problems During Implementation Of The New System

Since Packaging Specialties had previously been using solvent-base ink, it was a relatively easy transition to reacquaint all the printing presses and employees to solvent-base ink. The incinerator and ventilation system required an investment of about \$750,000. The only significant problem during this process concerned the functioning of the incinerator, as it

needed to be monitored to ensure that it disposed of the required VOC emissions. Initially, the incinerator experienced several operating problems, which implied periods where the VOC emissions were not being disposed of, potentially violating environmental regulations. One of the reasons for the occasional malfunctioning was a buildup of silicon in the incinerator, which deactivates the catalyst. Although the source of the silicon is unknown to the company, the problem has been resolved by cleaning the catalyst more frequently.

4. *Results Of The Change To The New Process*

The results of the first change from solvent-base to water-base ink have been documented previously in section 2. The change from water-base back to solvent-base ink with an incinerator was due to the poor but improving results of the water-base ink, and due to time constraints from the Arkansas Department of Pollution Control and Ecology, who in 1992 threatened huge fines on the company. Especially on substrates such as PVC and Cryovac, water-base ink did not meet the desired quality, and since the ink supplier(s) were not able to solve the problem, Packaging Specialties felt forced to use an incinerator. The quality, using solvent-base ink, is perceived to be more than satisfactory for all substrates, which is also reflected in the fact that there have been virtually no product returns or customer complaints based on the print quality. In 1989, Packaging Specialties emitted 702 tons of VOC's, without the incineration method. Currently, VOC emissions run at 35-40 tons per year, constituting a 95% decrease in VOC emissions.

5. *Impact of External Factors*

Packaging Specialties' ink supplier, GPI, was unable to create a water-base ink that would apply properly to the PVC and Cryovac substrates. GPI provides Packaging Specialties with an in-house ink technician who strongly favors solvent-base ink, as do the plant employees, who find it easier to work with solvent-base ink. However, their opinions did not play a substantive role in the company's decision making process. Management consulted Environmental Services Company, Inc., a Little Rock environmental consulting company, whose advice and recommendations played an important role in management's decision to purchase the current incinerator system.

6. *Future Developments*

Packaging Specialties hopes to implement both UV-base ink, which has reduced volatility content, and other environmentally-friendly inks in the future, to offset possible regulatory reduction in their VOC emission allowance. The use of PVC as a substrate is declining due to declining client demand, and is expected to disappear in the next ten years, contributing to the lack of commitment from ink vendors to develop a water-base ink for it. Furthermore, due to market growth, Packaging Specialties is expanding its operations at its current site, and believes the current incinerator can handle added VOC emissions.

FIRM X

Firm X, located in Nassau County, New York, was compliance-driven in 1990 to reduce its VOC emissions. At the time the local regulatory agencies (the Nassau County Department of Health and the New York State Department of Environmental Conservation) were not aware that the firm was violating its VOC emissions permit. Management took the first step on its own in determining how best to comply without regulatory prodding. The first attempt in 1990 to change from using solvent-base ink to water-base ink was unsuccessful, as at this stage the results were disappointing and management was not fully committed. The second attempt, completed in 1992 after nine months, was successful and will be further analyzed in this case study. The transfer to water-base ink is believed to be very successful as it has lowered 1995 VOC emissions to 8% of the 1990 VOC emissions.

1. *Facility Profile*

Number Of Employees:	Approximately 50
Annual Sales:	\$20 to 30 million (1995)
Sales Area:	Entire United States
Main Product:	Pattern coated polyolefin films
Plant Size:	31,000 square feet
Operating Schedule:	2 shifts/5 days a week
Printing Presses:	2 presses using chamber doctor blade systems with flexographic or gravure stations
Primary Ink:	Water-base
Primary Substrate:	Film and paper
Plate Making:	Out-sourced
VOC Emissions Permit:	Maximum of 25/yr.
Current Emissions:	Approximately 11 tons/yr.
Ink Cost:	Not available
Ink Waste:	Four 55 gallon drums/yr.
Ink Waste Cost:	\$2,200/yr. (\$550/55 gallon drum)

2. Issues Involved In Deciding To Use Water-Base Ink Vs. Add-On Controls

Management at Firm X attempted twice to convert to water-base ink in the early 1990's. After failing in 1990, management obtained assistance from a consultant versed in printing technology and environment compliance. The consultants' knowledge and expertise were instrumental in implementing water-base ink successfully to both presses at the facility during a nine month period. The major issue in this process was creating a water-base ink suitable for plastic, the primary substrate used. Management contacted fourteen ink manufacturers in 1991 and 1992, but none was able to supply a satisfactory water-base ink for the firm's substrate. Eventually, faced with losing Firm X's business, worth between \$0.5 - \$1.0 million annually, the company's main ink supplier (name was not made available), agreed to develop an ink to meet the firm's requirements. Although an incinerator system was reviewed, there were two major reasons in favor of using water-base ink:

1. the capital investment outlay of an incinerator was quoted by suppliers as being between \$1 and \$1.5 million, versus an estimated \$300 to \$400 thousand for converting to water-base ink.
2. the current site would be limited for planned growth and this would force the firm to move locations within a few years. This made installing an incinerator system on-site economically unworkable.

3. Issues And/Or Problems During Implementation Of The New System

As stated above in section 2, obtaining a satisfactory ink during the implementation phase was

a most difficult task. The problems were similar to those experienced by many others in the industry: the ink would not dry quickly enough and the density was unsatisfactory, which caused delays and/or poor quality products.

The substrate being printed needs a matte finish, whereas many other flexographic printers are concerned with obtaining the best possible gloss on their substrates. This facilitated the ink development process for the firm. Despite some problems with the ink, there were minimal returns from clients during this phase.

The conversion to water-base ink required a greater capital investment and higher operating costs than anticipated, due to:

- Increased equipment costs, such as new rollers, different plates, improved drying systems, doctor blades, etc. (dollar amounts were not available).
- Higher labor costs, as the water-base ink demands more sophisticated plant employees.
- Consulting fees (dollar amounts were not available).
- Opportunity loss, caused by lower productivity during the transfer phase (actual numbers were not available).

4. Results Of The Change To The New Process

All parties involved at Firm X are satisfied with the current operation of the flexographic presses, despite some negative impacts concerning the printing efficiency and cost.

The negative impacts include:

- Slower printing runs, approximately 25% less per day, due to water-base ink, resulting in lower productivity than with solvent-base ink (actual numbers were not available).
- Increased labor costs, as water-base ink requires more sophisticated personnel to monitor the process (dollar amounts were not available).
- Higher ink costs, estimated at 15% more than solvent-base ink (dollar amounts were not available).

The positive impacts include:

- Cost savings, as the firm would have invested considerably more for an incinerator system, and would have encountered high operating expenses for the Natural Gas to fuel the system (dollar amounts were not available).
- Higher cost of water-base ink is somewhat mitigated by the better mileage using water-base ink than using solvent-base ink (dollar amounts were not available).
- Recovered water-base ink is recycled without filtering, which simultaneously improves the color quality.
- Firm's annual VOC emissions is less than half the permitted 25 tons of VOC with water-base ink.
- Safe and friendly environment for employees.
- Cleaning of rubber plates and equipment is less hazardous (much of it can be accomplished simply using water).
- Only one 55 gallon drum of ink waste is produced each quarter at a disposal cost of approximately \$550 each. Information from previous years was not made available.

5. *Impact of External Factors*

As documented earlier, the consultant played a pivotal role in helping Firm X to convert to water-base ink, as well as operate in compliance with environmental regulations. As members of the Flexographic Technical Association, the company was able to follow progress in technology through the publications and meetings of the FTA. The role of the main ink supplier was also crucial, as it eventually did find the right balance of composition of the water-base ink. But most significant of all was the commitment of the current president and his management team to installing a pollution prevention program at the facility.

6. *Future Developments*

The firm is seeking to work with other substrates in order to move the company into other markets and increase its performance. There has been increased pressure from some clients to have Firm X conform to the ISO 9000 guidelines. ISO 9000 is a series of standards which were developed by a technical committee of the International Standardization Organization (ISO) to harmonize manufacturing quality requirements internationally. These standards contain requirements for the elements of an effective quality management system, including compliance with environmental guidelines. Companies that wish to comply must require their suppliers to do so as well, hence, the pressure from Firm X's customers. The issue of compliance with ISO 9000 seems inevitable, and management has undertaken efforts in this direction, but prefers not to specify those efforts in this study.

FINDINGS

This study has made the following findings regarding the emission reduction experiences of the three flexographic printing facilities:

1. Several key factors consistently arose as the companies in the study evaluated their emission reduction experiences. Some make the solvent-base ink and incinerator method of VOC compliance more attractive to printers. These include:
 - Gloss, which adds considerably to the quality of the printed image, and is considered easier to achieve using solvent-base ink than water-base ink;
 - Price, as solvent base-ink generally costs 10-20% less than water-base ink;
 - Speed of the presses, as solvent-base ink generally allows 10-20% faster runs than water-base ink;
 - Ease of operation, using solvent-base ink is considered the simpler solution for press operators, but requires the installation of an incinerator system.

On the other hand, several important factors weigh in favor of the water-base ink approach.

These include:

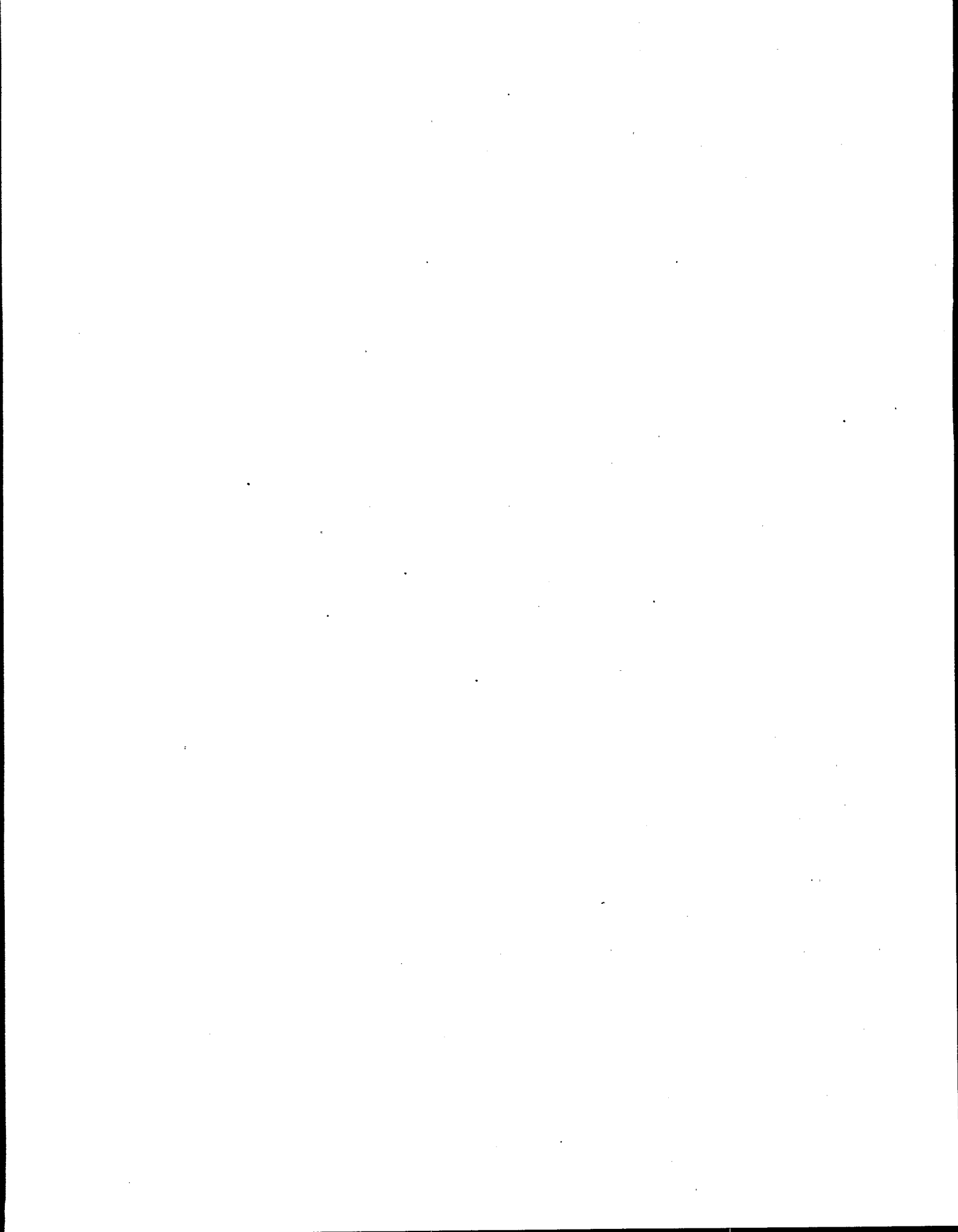
- Initial capital investment, as the water-base ink method is more economical than the incinerator method;
- Ink mileage, with water-base ink exceeding solvent-base ink by 15-30%;
- Color consistency, which is better maintained with water-base ink; and
- Working environment for employees, which is safer.

2. The two facilities studied which successfully converted to water-base ink concluded that doctor blade boxes (preferably enclosed) are essential on all flexographic presses. Doctor blades improve ink distribution by wiping excess ink off the anilox roller, while enclosing the doctor blades eliminates evaporation loss. At Packaging Specialties, during the time of using solely water-base ink, none of the presses operated using doctor blades, which partially explains the failure of the conversion to water-base ink and the resulting decision to revert to solvent-base ink and install an incinerator system.

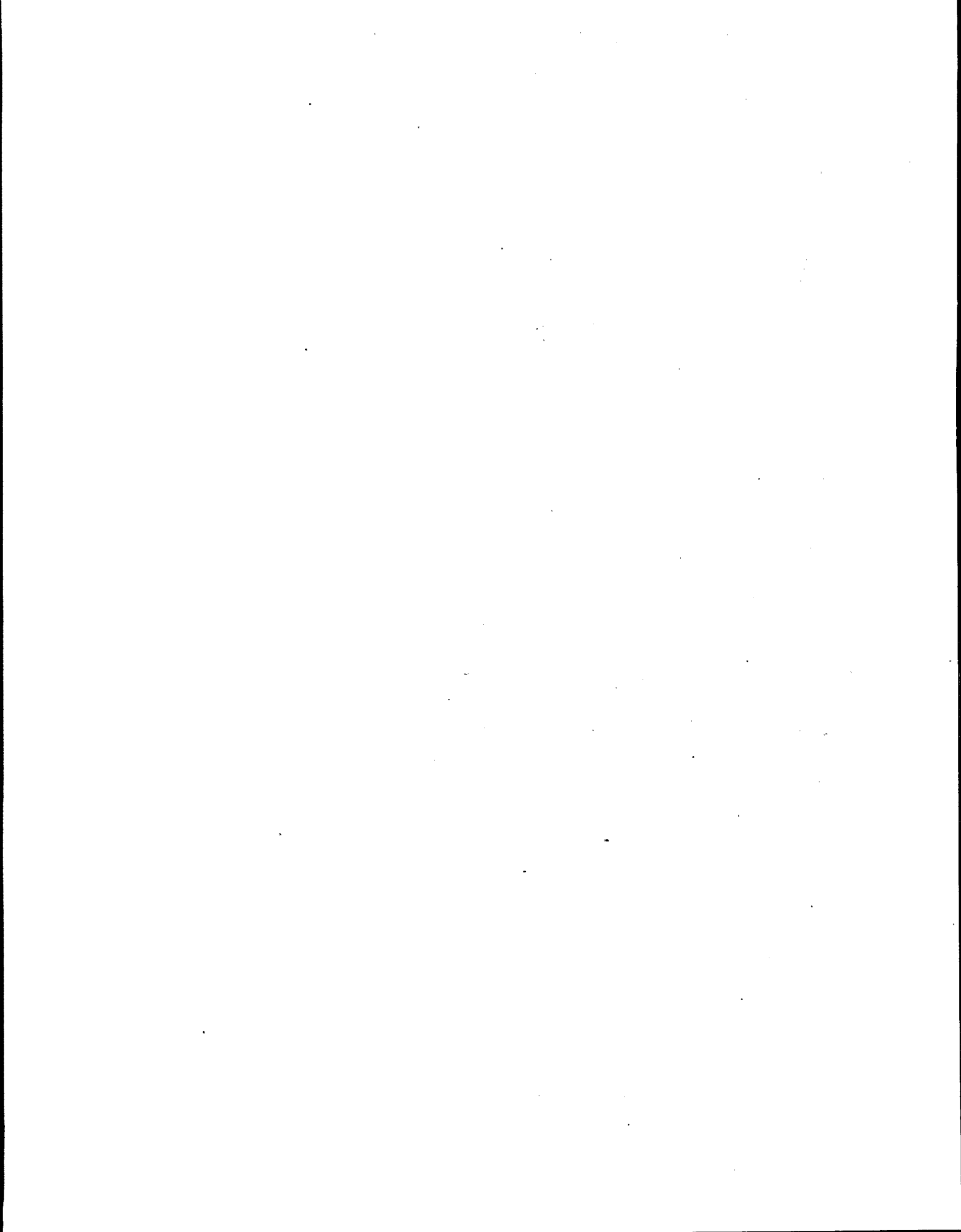
3. In each case, the ability and willingness of the ink supplier to work with the printer in developing an effective water-base ink was key to success or failure of the conversion. Flexographic printers rely on the ink suppliers to develop an ink that will meet the company's requirements regarding speed, gloss, consistency, price, and mileage. This applies, in particular, to the development of water-base ink for less used substrates, as those seem to be neglected for economic reasons.

References

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- ¹⁷ EPA, Profile of the Printing Industry. August 1995. EPA 310-R-95-014.
- ¹⁸ EPA, Profile of the Printing Industry. August 1995. EPA 310-R-95-014.



Appendix A



7,500 CFM CATALYTIC INCINERATOR - THREE PRESSES*Based on Possible Reduction of Air Flow from 18,500 CFM Theoretical*

Annual Operating Costs	Total Costs	Percent	Annual Costs
1. Cost of Unit	included		
Installation (estimated)	included		
Total Costs of System	\$350,000		
2. Less Down Payment	35,000		
3. Financed Amount	315,000		\$31,500
4. Interest Amounts*	184,530	10.0%	18,453
5. Operating Costs			
A. Electricity			15,100
B. Natural Gas			14,060
C. Catalyst			8,000
D. Maintenance			10,000
E. Indirect Costs			0
Total Operating Costs			47,160
6. Total Cost of Controls			97,113
7. Deduct Tax Savings (35 %)			63,123
8. VOC REDUCTIONS			
A. Tons emitted Per Projection based on 1993-94 Purchases			18.30
B. Percent Reduction Required			60%
C. Tons Reduced			10.98
TOTAL COST OF CONTROLS PER TON REDUCED			\$5,749

* Interest accrued over ten year period

Notes:

1. Equipment Life - ten years
2. Electrical based on vendors' data - \$7.55/hour; may be high for Baltimore.
3. Natural gas based on vendors' data - \$7.03/hour; may be high for Baltimore.
4. Catalyst replacement based on attrition over seven years.
5. Maintenance; labor and parts estimated at \$10,000 minimum.

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Annual Operating Costs	Total Costs	Percent	Annual Costs
1. Cost of Unit	97,600		
Installation (estimated)	20,000		
Total Costs of System	117,600 est.		
2. Less Down Payment	11,760		
3. Financed Amount	105,840		\$10,584
4. Interest Amounts*	91,361	14.0%	9,136
5. Operating Costs			
A. Electricity			960
B. Natural Gas			3,840
C. Catalyst			1,428
D. Maintenance			2,500
E. Indirect Costs			0
Total Operating Costs			8,728
6. Total Cost of Controls			28,448
7. Deduct Tax Savings (35 %)			18,491
8. VOC REDUCTIONS			
A. Tons emitted Per Projection based on 1993-94 Purchases			4.70
B. Percent Reduction Required			60%
C. Tons Reduced			2.82
TOTAL COST OF CONTROLS PER TON REDUCED			\$6,557

* Interest accrued over ten year period.

Note:

1. Equipment life - ten years

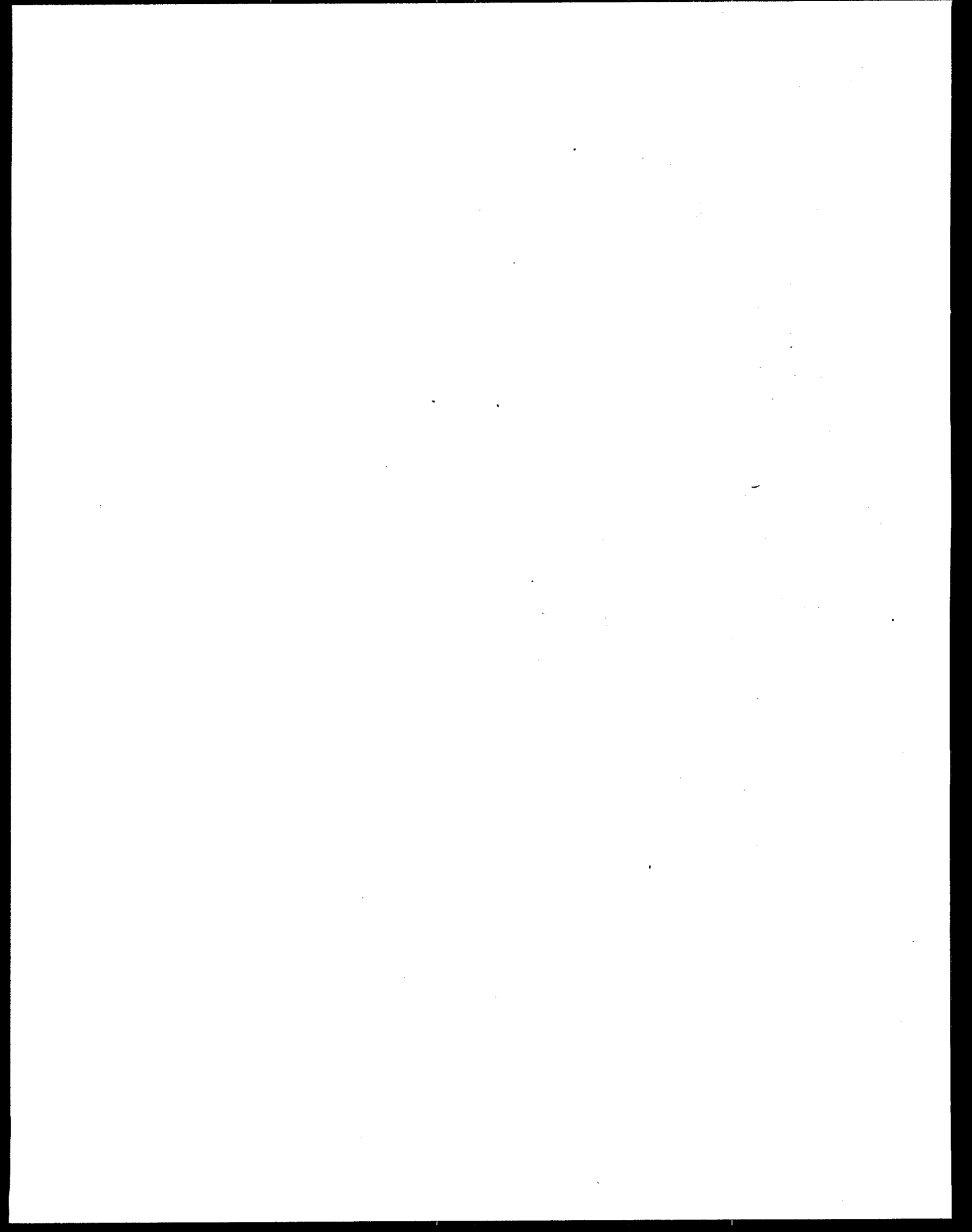
5,000 CFM

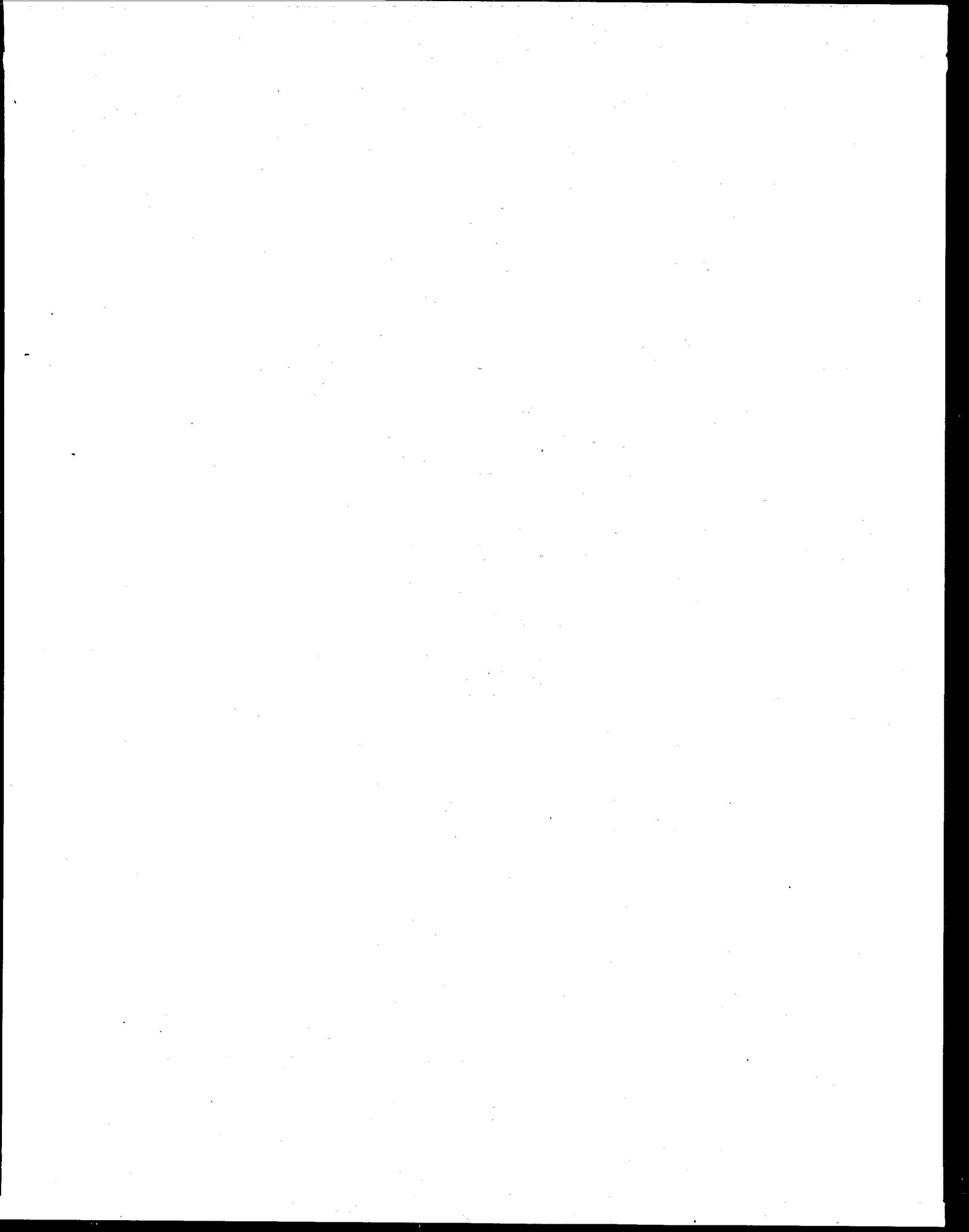
Annual Operating Costs	Total Costs	Percent	Annual Costs
1. Cost of Unit	201,576		
Installation (estimated)	0		
Total Costs of System	201,576		
2. Less Down Payment	20,158		
3. Financed Amount	181,418		18,142
4. Interest Amounts*	82,714	8.0%	8,271
5. Operating Costs			
A. Electricity			7,960
B. Natural Gas			9,600
C. Catalyst			1,755
D. Maintenance			5,000
E. Indirect Costs			0
Total Operating Costs			24,315
6. Total Cost of Controls			50,728
7. Deduct Tax Savings (35 %)			32,973
8. VOC REDUCTIONS			
A. Tons emitted Per Projection based on 1993-94 Purchases			49.03
B. Percent Reduction Required			60%
C. Tons Reduced			29.42
TOTAL COST OF CONTROLS PER TON REDUCED			\$1,121

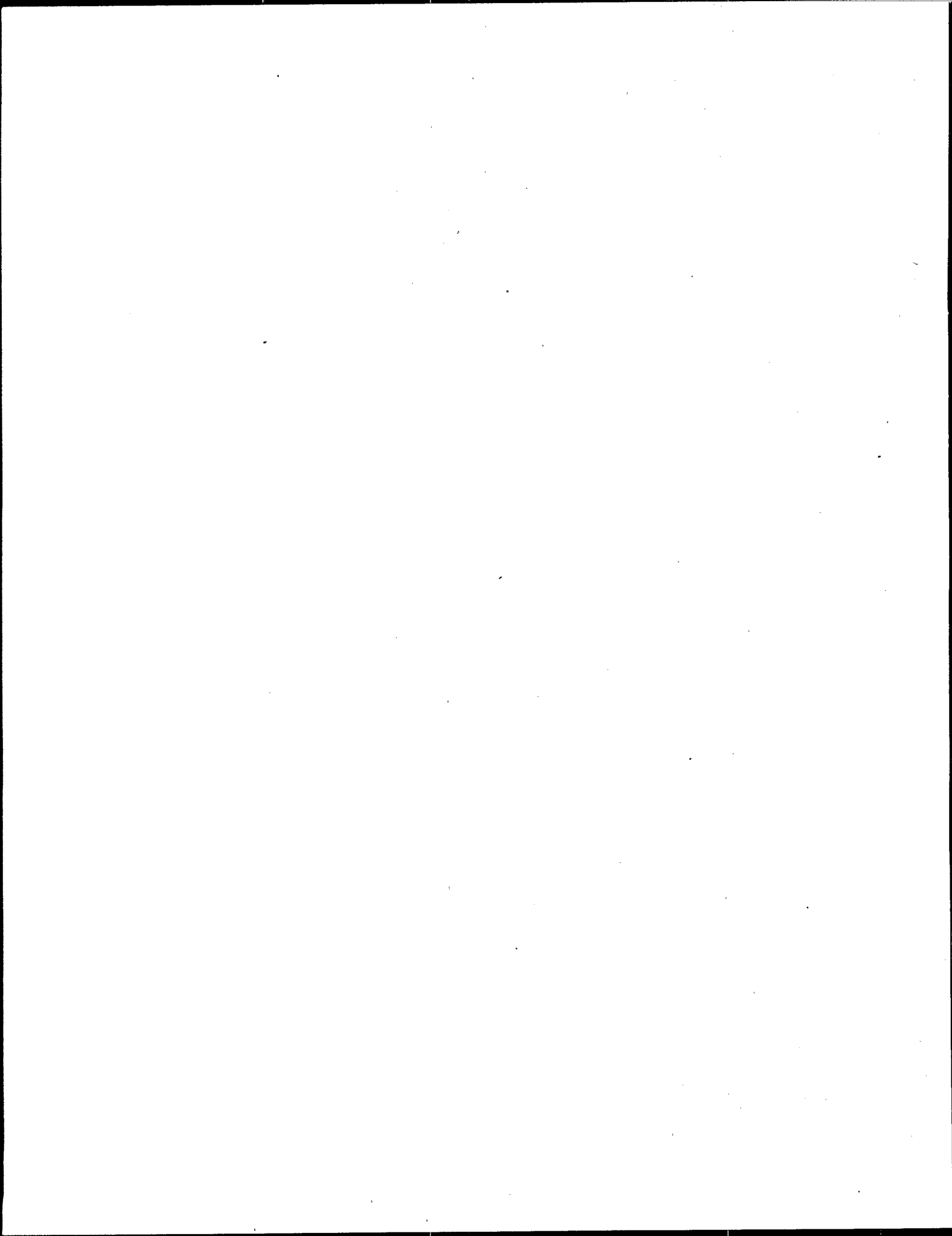
* Interest accrued over ten year period.

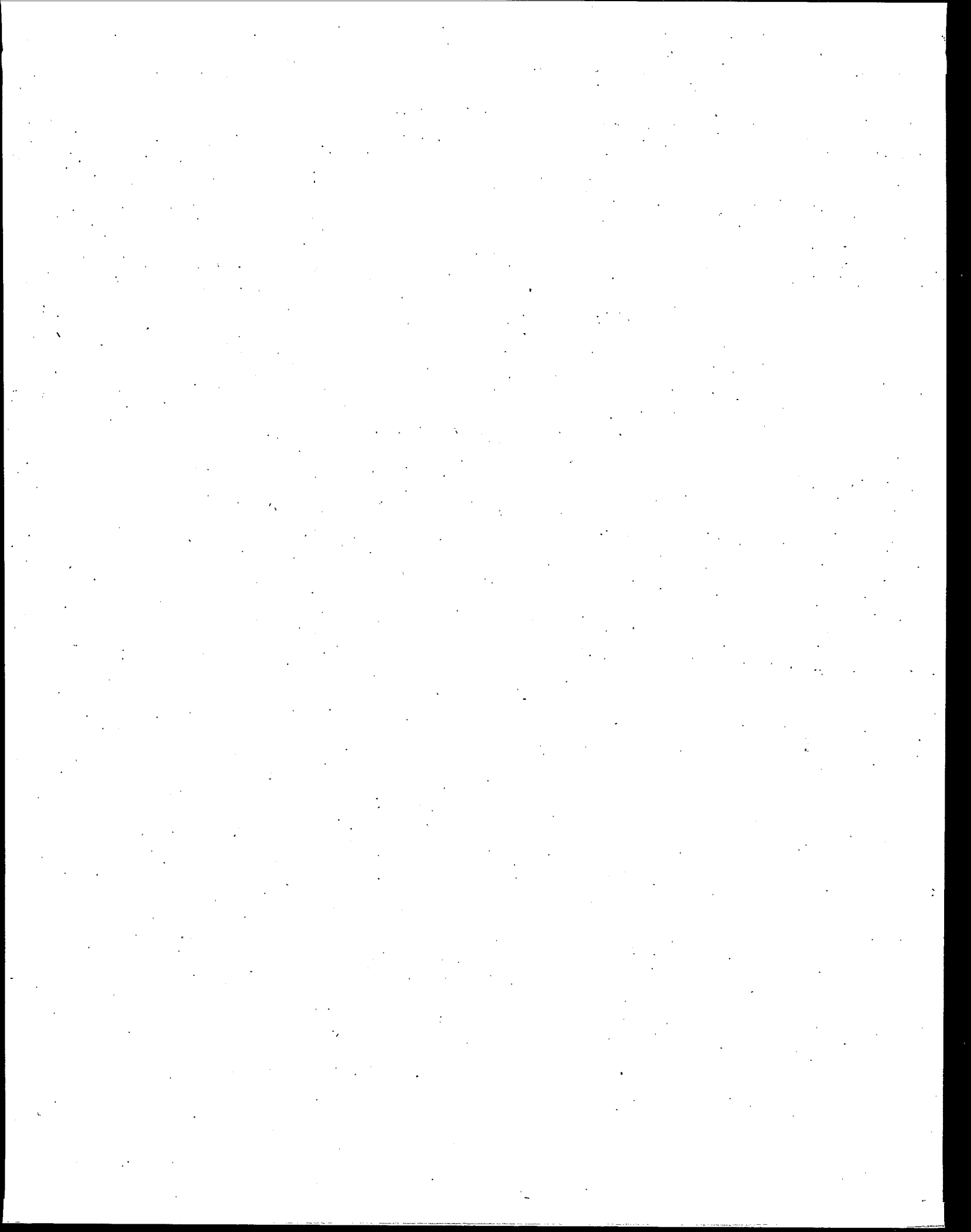
Notes:

1. Equipment Life - ten years
2. Electrical based on \$1.99/hour; DEC-E-TEC at 402,300 BTU.
3. Natural gas based on \$2.40/hour; DEC-E-TEC at 402,300 BTU.
4. Catalyst replacement based on attrition over seven years.
5. Maintenance; labor and parts estimated at \$5,000 minimum.











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Environmental Protection Agency
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\$300